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ENGINEERING DESIGN FILE

Project/Task In Situ Vitrification Project
Subtask Intermediate Field Test

EDF Page 1 of 20

Subject: Calculation of Off Gas Concentrations During ISV Process

Abstract:

This EDF indicated that during normal operation of the ISV intermediate scale facility, the concentrations of CO and H_2 are expected to be below the LEL for these gases in dry air by a factor of 10, 0.49% and 0.43%, respectively. The 10% of LEL, the upper level at which the facility will operate, are levels for explosive gases which are acceptable for personnel entry into an enclosure. The gas concentration coming off the melt and prior to mixing with the incoming air into the hood was determined for the worst case which is in Pit 2 at the bottom of the pit where the pallets for the boxes are. These concentrations were 14.5% for CO and 25.7% for H_2. Adequate air flow into the hood is essential to combust the pyrolyzed gases and to produce a safe off gas stream for release to the environment.

Administrative control for the off-gas system specifies if the stack CO concentration is greater than 0.1%, the CO concentration will be monitored in the operation trailer. Therefore, the personnel in the trailer are guaranteed that they are not being exposed to CO concentration as being released from the stack. If the CO concentration in the stack exceeds 2.5%, action will be taken by the operator to lower the emission of CO, otherwise the facility will be shutdown.

If the blower operation is disrupted, operation should be concerned with the potential of increased concentration of CO and H_2 in the hood. The lack of reactive air will cause the concentration to increase possibly to levels that these gases are being released from the melt surface and these levels are higher than the LEL for these gases in dry air. It is recommended that a study be conducted to consider the occurrence of blower outage and to determine the time for safe restart (concentration of gases are below their LEL for dry air).

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1. INTRODUCTION

In the process of In Situ Vitrification of soil and subsequent layers of a mixture of different waste materials, combustible materials will pyrolyze to gases, primarily carbon monoxide and hydrogen. Both of these gases are flammable and are potentially explosive if concentration levels are above their lower flammability limit. A detailed study of the off gases from the vitrification of two test pits which simulate radioactive waste landfill at the Subsurface Disposal Area (SDA) at the Radioactive Waste Management Complex (RWMC) on the Idaho National Engineering Laboratory (INEL) was performed and reported here. The molecular or elemental concentration in the materials, which were used in the demonstration pits, were determined from vendor data or handbook references on typical material. A simplified approach was used to determine the primary reactions for the product gases of concern. The simplified approach did not consider interaction of all elements or molecules, particulate carry over, reaction rates with controlling factors, and reaction times.

2. PIT DESCRIPTION

The construction of the two pits for the demonstration tests of the intermediate-scale in situ vitrification facility is recorded in a log book, BWP-006 and are a 10 foot by 10 foot area which extended 10 feet below the surface of the ground. They are located just outside the fence on the north side of the Water Reactor Research Test Facility (WRRTF) in the Test Area North (TAN) of the INEL. The bottom of the each pit is filled with two feet of SDA lakebed soil from RWMC. The next six feet is a waste deposit which is a mixture of various waste to simulate a SDA. The upper two feet is again SDA lakebed soil to simulate the soil cap of the SDA. Prior to starting the facility operation a two inch deep trench is dug around and between the electrodes and is filled with graphite and a mixture of graphite and glass frit.

The waste deposit is constructed to simulate drums and boxes filled with radioactive waste as disposed at the SDA. The 55-gallon drums were simulated by carbon steel containers manufactured by Cental Can Company of Chicago. The containers are approximately 2.5 gallons capacity and 1.75 pounds. A lid was provided for each container and could be crimped to contain the waste. The lids were crimped in a few locations but no effort was made to crimp tightly to seal the drums (cans will not hold appreciable pressure). The boxes were simulated with standard cardboard boxes manufactured by Tharco Company of Salt Lake City. For structural strength, each box actually consisted of two boxes, an inner and outer box. The inner box (TW-148) measured 30" by 18" by 16" and the outer box (TW-682) measured 30.5" by 18.5" by 18.5". The combined weight was 8 pounds. The daily log book BWP-006 records the detailed filling of the drums and boxes.

The waste materials consisted of simulated sludge, combustibles, concrete/glass, metal, and wood. None of these materials are radioactive and material obtained from the waste piles on INEL were inspected prior to placing them in the drums or boxes. The simulated sludge was made by mixing Micro-Cel E, Floor Dri, and water in the portions of 2.3065 lbs, 0.70 lbs, and 7.7097 lbs, respectively. Micro-Cel E was purchased from Manville Corporation, Filtration & Minerals Division, Denver Colorado, 80217-5108 (303/978-2000). Floor Dri was purchased from Eagle-Picher, Reno, Nevada, 89510 (702/322-3331). The water was service water at the test site. The combustibles consisted of paper and cloth. The paper was obtained from INEL excess and was scrap computer paper. The cloth was also obtained from INEL excess and was used combat fatigues excessed from the INEL security contractor. The concrete was obtained from a scrap pile 200-300 yards southeast of the southeast corner of WRRTF and was verified to be free of radioactive material by TAN HP. The glass was purchased from American Recycling, Idaho Falls and consisted of broken bottle glass as received by the recycling center. Metal consisted of scrap carbon steel and stainless steel from scrap piles on site and at Pacific Steel (4170 lbs of carbon steel and 3330 lbs of stainless steel). The wood was obtained from INEL cold dumpsters.

Figure 1 details the construction of Pit 1. Table 1 gives the break down of the amount of the various materials used in pit 1.

Depth View of Pit 1; the surface area is 10′ x 10′

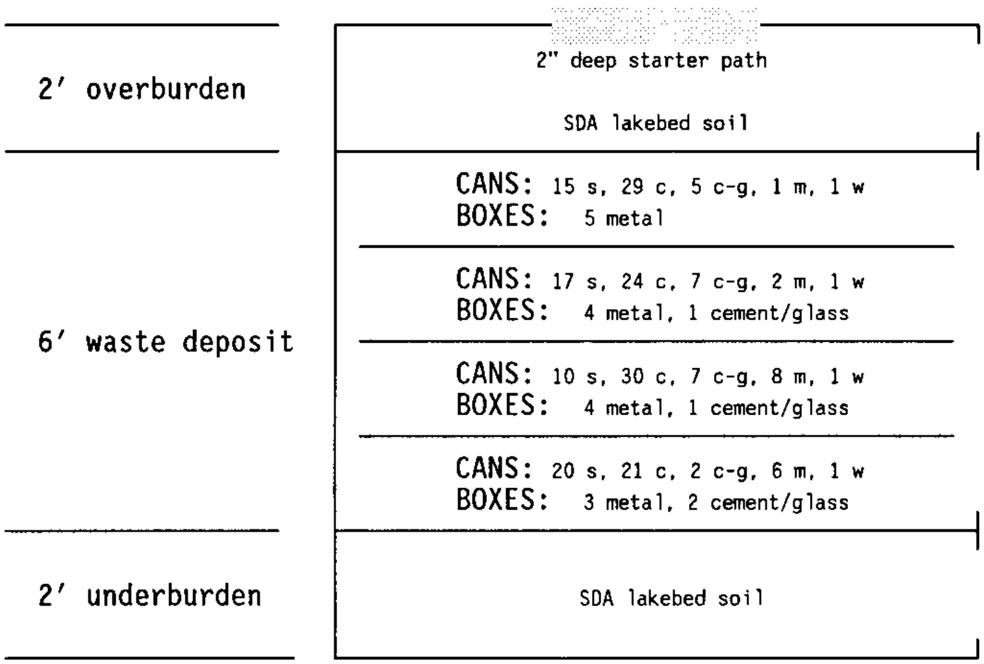


Figure 1. Pit 1 illustration of construction.

The "s" indicates sludge cans, "c" is combustible cans, "c-g" is concrete/glass cans, "m" is metal cans, and "w" is wood cans. These designations indicate the contents of the cans. These cans contained the following, approximate amounts of material:

Sludge can (s) - 10.716 lbm
(7.71 - H20, 0.70 - Floor Dri, 2.307 - Micro-Cel E.)
Combustible can (c) - 4.154 lbm
(1.637 - Cloth, 2.517 - Paper)
Concrete/glass can (c-g) - 17.440 lbm
(11.035 - concrete, 6.405 - glass)
Metal can (m) - 8.235 lbm
(4.118 - carbon steel, 4.118 stainless steel)
Wood can (w) - 4.875 lbm
Pallet - 13.5 lbm of wood

Boxes contained the following, approximate amounts of material:

Metal - 123.0625 lbm (50% carbon steel)
Concrete/glass - 246.375 lbm (158.75 - concrete, 87.625 - glass)

Table 1. Pit 1 waste deposit material composition in pounds.

MATERIALS	TOTAL		ITEM WEIGHT	WASTE DEPOSIT LAYERS TOP	3RD	2ND	BOTTOM
COMBUSTIBLES:	665.5						
Cans:		451.5					
Paper			261.75	72.99	60.40	75.51	52.85
Cloth			170.25	47.47	39.29	49.11	34.38
Wood			19.50	4.88	4.87	4.88	4.87
Boxes:		214.0					
Cardboard			160.00	40.00	40.00	40.00	40.00
Pallet (wood)			54.00	0.00	13.50	13.50	27.00
SLUDGE: (cans only)	664.4						
Water		478.0	478.00	115.65	131.06	77.10	154.19
Floor Dri		43.4	43.40	10.50	11.90	7.00	14.00
Micro-Cel		143.0	143.00	34.50	39.20	23.10	46.20
METALS:	2,473.0						
Cans:		504.0					
Stainless			70.00	4.12	8.24	32.94	24.70
Carbon Steel			434.00	93.37	97.49	130.94	112.20
Boxes:		1,969.0					
Stainless			984.50	307.65	246.13	246.13	184.59
Carbon Steel			984.50	307.65	246.13	246.13	184.59
CONCRETE/GLASS:	1,351.75						
Cans:		366.25					
Concrete			231.75	55.18	77.25	77.25	22.07
Glass			134.50	32.03	44.83	44.83	12.81
Boxes:		985.5					
Concrete			635.00	0.00	158.75	158.75	317.50
Glass			350.50	0.00	87.62	87.63	175.25
TOTALS OF COLUMNS	5,154.65		5,154.65	1,125.99	1,306.66	1,314.80	1,407.20

Figure 2 details the construction of Pit 2. Table 2 gives the break down of the amount of the various materials used in pit 2.

Depth View of Pit 2; the surface area is 10′ x 10′

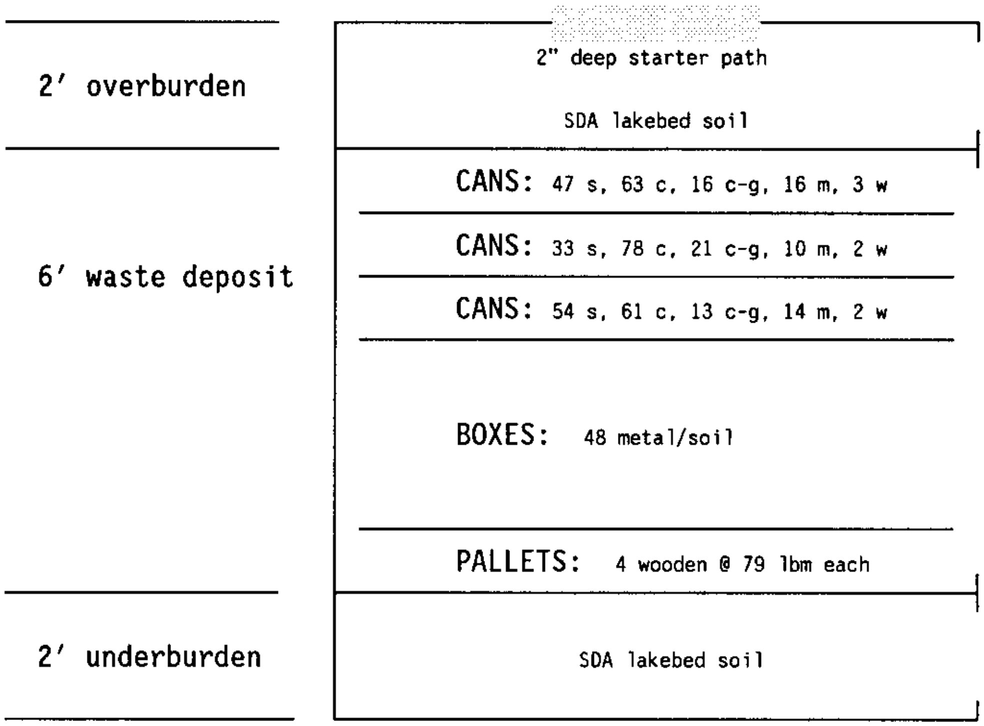


Figure 2. Pit 2 illustration of construction.

The "s" indicates sludge cans, "c" is combustible cans, "c-g" is concrete/glass cans, "m" is metal cans, and "w" is wood cans. These designations indicate the contents of the cans. These cans contained the following, approximate amounts of material:

Sludge can (s) - 10.72 lbm
(7.72 - H2O, 0.70 - Floor Dri, 2.307 - Micro-Cel E.)
Combustible can (c) - 3.96 lbm
(1.901 - Cloth, 2.059 - Paper)
Concrete/glass can (c-g) - 16.73 lbm
(12.0 - concrete, 4.73 - glass)
Metal can (m) - 6.58 lbm
(3.29 - carbon steel, 3.29 stainless steel)
Wood can (w) - 3.14 lbm
Pallet - 79.0 lbm of wood

Boxes contained the following, approximate amounts of material:

Metal/soil - 119.521 lbm (50% carbon steel)
244.021 lbm soil

Table 2. Pit 2 waste deposit material composition in pounds.

MATERIALS	TOTAL		ITEM WEIGHT	WASTE DEPOSIT LAYERS TOP CAN	MID CAN	BOT CAN	BOXES	PALLETS
COMBUSTIBLES:	1,513.5							
Cans:		813.5						
Paper			411.50	128.24	159.13	124.13		
Cloth			380.00	118.43	146.94	114.63		
Wood			22.00	9.42	6.29	6.29		
Boxes:		700.0						
Cardboard			384.00				384.00	
Pallet (wood)			316.00					316.00
SLUDGE: (cans only)	1,436.5							
Water		1,034.5	1,034.50	362.85	254.77	416.88		
Floor Dri		93.8	93.80	32.90	23.10	37.80		
Micro-Cel		308.2	308.20	108.10	75.90	124.20		
METALS:	6,757.95							
Cans:		1,020.95						
Stainless			131.60	52.64	32.90	46.06		
Carbon Steel			889.35	306.39	284.90	298.06		
Boxes:		5,737.0						
Stainless			2,868.50				2,868.50	
Carbon Steel			2,868.50				2,868.50	
CONCRETE/GLASS:	12,549.50							
Cans:		836.50						
Concrete			236.50	75.68	99.33	61.49		
Glass			600.00	192.00	252.00	156.00		
Boxes:								
Soil		11,713.00	11,713.00				11,713.00	
TOTALS OF COLUMNS	22,257.45		22,257.45	1,386.65	1,335.26	1,385.54	17,834.00	316.00

3. MATERIAL COMPOSITION

The composition of the material was obtained from vendors, but if vendor data was not available a handbook composition was used. The materials are soil, paper, wood, cardboard, cloth, Floor Dri, Micro-Cel E, carbon steel, stainless steel, glass, and concrete which is a mix of cement and sandstone.

The chemical composition of the various materials placed in the pits are listed in the following tables.

Table 3. Chemical composition of Soil

ELEMENT	WEIGHT PERCENT
Silicon Oxide (SiO_2)	62.60
Aluminum Oxide (Al_2O_3)	11.85
Iron Oxide (Fe_2O_3)	4.25
Calcium Oxide (CaO)	3.68
Potassium Oxide (K_2O)	2.99
Magnesium Oxide (MgO)	1.72
Sodium Oxide (Na_2O)	1.37
Titanium Oxide (TiO_2)	0.68
Manganese Oxide (MnO_2)	0.10
Barium Oxide (BaO)	0.09
Zirconium Oxide (ZrO_2)	0.05
Boron Oxide (B_2O_3)	0.05
Nickel Oxide (NiO)	0.04
Strontium Oxide (SrO)	0.02
Chromium Oxide (Cr_2O_3)	0.02
Water (H_2O)	7.50
Other inert	2.62*
Organic	0.13*
Sulfur trioxide (SO_3)	0.11*
Chloride (Cl)	0.07*
Phosphorus Oxide (P_2O_3)	0.06*

The data was taken from soil analysis presented by the Battele Pacific Northwest Laboratories (PNL) in the Test Plan for the Intermediate-scale Testing of ISV and from chemical composition of silt and loess in the Practical Handbook of Physical Properties of Rocks and Minerals, CRC Press, Inc., 1989 *. The major elements were as reported by PNL and the deficient elements were added as listed in the Handbook. Other inert was the balancing constituent.

Table 4. Chemical Composition of Paper.

ELEMENT	WEIGHT PERCENT
Carbon (C)	42.18
Hydrogen (H)	5.795
Oxygen (O)	46.835
Water (H_2O)	5.00
Sulfur (S)	0.19

The carbon, hydrogen, and oxygen ratio was the value used by PNL in their analysis for the combustion products for off gas loading on the hood. The water and sulfur composition were added to incorporate information from Perry's Chemical Engineers Handbook,Fifth Edition, p. 9.8 in which the Waste Fuel Analyses indicated that paper had 0.2% sulfur, 6% ash and 10.2% moisture. The moisture value was estimated at half the value listed (this would be a more conservative water release because the condition of the paper was not known). The sulfur value was adjusted to total 100 percent.

Table 5. Chemical Composition of Wood.

ELEMENT	WEIGHT PERCENT
Carbon (C)	42.34
Hydrogen (H)	5.42
Oxygen (O)	37.14
Sulfur (S)	0.10
Water (H_2O)	14.00
Calcium (Ca)	0.63
Sodium (Na)	0.37

The data for wood was obtained from Marks' Standard Handbook for Mechanical Engineers, Eighth Edition, p. 6-122 and was stated as about 40-50% cellulose, 15-35% lignin, less than 1% mineral, 20-35% hemicellulose, and the remainder extractable matter of a variety of sorts. From Perry's Chemical Engineers' Handbook, Fifth Edition, p. 9.8 it was noted that wood contained 20% moisture, 0.05% sulfur, and 1.0% ash or minerals. The values were adjusted so that the total would be 100%, yet the value was within reference ranges.

Table 6. Chemical Composition of Cardboard.

ELEMENT	WEIGHT PERCENT
Carbon (C)	42.18
Hydrogen (H)	5.795
Oxygen (O)	46.835
Sulfur (S)	0.19
Water (H_2O)	5.00

The composition of cardboard was assumed similar to paper which included cellulose molecular formula with adjustments for sulfur and water. For details see discussion following Table 4.

Table 7. Chemical Composition of Cloth
(60% Polyester; 40% Cotton).

ELEMENT	WEIGHT PERCENT
POLYESTER	(60)
Carbon (C)	59.375
Hydrogen (H)	3.962
Oxygen (O)	31.663
Water (H_2O)	5.000
COTTON	(40)
Carbon (C)	42.218
Hydrogen (H)	5.871
Oxygen (O)	46.911
Water (H_2O)	5.000

The values for cloth were generated from data from the book Organic Chemistry, Cram, D.J. and Hammond, G.S., McGraw-Hill Book Company, 2nd Edition, 1964, pp. 689 and 695.

Table 8. Chemical Composition of Sludge.

ELEMENT	WEIGHT PERCENT
Water (H_2O)	
Micro-Cel	
SiO_2	56.0
Al_2O_3	3.8
Fe_2O_3	1.0
CaO	26.0
MgO	0.7
Na_2O	0.6
K_2O	0.6
LOI	11.3
Floor Dri	
SiO_2	89.2
Al_2O_3	4.0
Fe_2O_3	1.5
CaO	0.5
MgO	0.3
Na_2O	0.25
K_2O	0.25
H_2O	4.0

The data for Micro-Cel E was obtained from the manufacturer Manville Corporation, Filtration & Minerals Division, Denver, Colorado, 80217-5108, (303/978-2000). The LOI (Loss On Ignition) is assumed to include water and other nonhazardous volatile material. The data for Floor Dri was obtained from Mr. Pat Flynn of Eagle-Picher, Reno, Nevada, 89510, (702/322-3331).

Table 9. Chemical Composition of Metals.

ELEMENT	WEIGHT PERCENT
Carbon Steel	
Carbon	0.6
Manganese	1.0
Phosphorus	0.035
Sulfur	0.04
Silicon	0.35
Nickel	0.7
Chromium	0.6
Molybdenum	0.3
Iron	96.375
Stainless Steel	
Carbon	0.08
Manganese	2.0
Silicon	1.0
Nickel	10.0
Chromium	20.0
Molybdenum	3.0
Iron	63.92

The values for steels were obtained from Marks' Standard Handbook for Mechanical Engineers, Eighth Edition, pp. 6-33 and 6-37. Values approximate AISI 8655 carbon steel and 316 stainless steel.

Table 10. Chemical Composition of Glass.

ELEMENT	WEIGHT PERCENT
SiO_2	73.0
Al_2O_3	1.5
CaO	10.0
Na_2O	12.0
MgO	3.0
BaO	0.5

The values for glass were approximated from data presented in The Encyclopedia of Engineering Materials and Processes, Reinhold Publishing Corporation, New York, p. 297. The composition was for soda-lime glass for window sheet which is very similar to container glass.

Table 11. Chemical Composition of Concrete (cement and sandstone).

ELEMENT	WEIGHT PERCENT
SiO_2	68.136
TiO_2	0.205
Al_2O_3	5.157
Fe_2O_3	1.403
FeO	0.245
MgO	1.410
CaO	15.877
Na_2O	0.369
K_2O	1.073
H_2O	1.335
P_2O_5	0.066
CO_2	4.120
SO_2	0.057
SO_3	0.311
BaO	0.041
R_2O_3	0.148
OTHER	0.047

The values for concrete were generated from data in Marks' Handbook and Practical Handbook of Physical Properties of Rocks and Minerals.

4. CALCULATION AND ASSUMPTIONS DISCUSSION

The process of in situ vitrification will cause the material in the pit to vaporize, decompose/pyrolyze, or melt. The vaporization and decomposition/pyrolysis of the material is a major concern. The reactions of a mixture of various material can be very complex. This analysis will be simplified and will only be concerned with vaporization of inorganics and pyrolysis of organics to hydrogen and carbon monoxide. The vaporization of any of the material constituents (inorganic) is based wholly on the boiling or vaporization temperature of the pure substance. If the boiling temperature is less than or equal to 1000°C, the constituent will be included into the off-gas gases. The combustible or organic constituents, which will pyrolyze at the operating temperature of ISV, are assumed to break down completely to carbon monoxide and hydrogen; any oxygen in excess from the formation of carbon monoxide will be combined with any carbon, which is available in the melt, to form carbon monoxide. The vaporized material will be considered as inert and will not affect the two reactions for combustion of carbon monoxide and hydrogen when the melt off gases contact the air (oxygen). Other reactions will be considered negligible and will not compete for the oxygen. Also carry-over of any particulates will not be considered. All carbon will be treated as an off gas even though in actuality a portion may remain in the melt. This evaluation (which will give a conservative or upper bounding value) is a very simplified approach to determine the concentration of hydrogen and carbon monoxide that will be present in the off gas and in the off-gas system after the reaction or combustion of these gases in air at the surface of the melt in the hood.

The base constituents are defined as the elements or molecules as listed in Tables 3 - 11. These base constituents will not be changed during the process except for the constituents of the combustible materials (paper, cloth, wood, cardboard) and carbon. The combustibles (organic matter) will be composed primarily of carbon, hydrogen, and oxygen. The carbon will be combined with oxygen to form carbon monoxide; the hydrogen will be combined with itself to form hydrogen gas (H_2). Any excess oxygen will combine with carbon from other organic matter or metals to form more carbon monoxide. The inorganic base constituents will mainly stay in the melt or will off gas if the constituents boiling point is less than or equal to 1000°C. In general, the base constituents of sludge, soil, metal, and concrete/glass will not be pyrolyzed, and will be found in the melt or in the off gas as a condensable gas. The base constituents of the combustibles will be pyrolyzed and will be reacted with air to form carbon dioxide and water.

The calculation, first, determined the amount/hour of each constituents in the melt by summing the amount loaded in the pit and multiplying this times the melt rate (3.5 inches/hour).

$$Y = \Sigma L \ * \ 3.5$$

where L = load rate, lbm/inch of depth,
Y = off gas rate, lbm/hour.

With a known amount of C, H, and O, the amount of CO and H_2 is determined by combining the carbon with oxygen to form carbon monoxide, and combining the hydrogen with another hydrogen to form molecular hydrogen, H_2. The excess oxygen will be combined with carbon in the other materials to form carbon monoxide (therefore no oxygen will be leaving the melt). These reactions can be stated in the following equations:

$$C_xH_yO_z \xrightarrow{\text{PYROLYSIS}} xC + yH + zO$$
$$xC + yH + zO \xrightarrow{\text{PYROLYSIS}} xCO + (y/2)H_2 + (z-x)O$$
$$aC + (z-x)O \xrightarrow{\text{PYROLYSIS}} (z-x)CO + (a-z+x)C$$

With the amount of CO and H_2, the amount of CO_2 and water (H_2O) is determined by multiplying the reaction percentage by the amount of CO and H_2 to yield the amount of carbon dioxide and water that will be formed. The remaining amount of CO and H_2 will off gas to the off-gas treatment system. Two moles of CO or H_2 are required to react with one mole of molecular oxygen, O_2, to form CO_2 and water, H_2O. The reaction equations for this combustion are

$$2CO + O_2 \xrightarrow{\text{COMBUSTION}} 2CO_2$$
$$2H_2 + O_2 \xrightarrow{\text{COMBUSTION}} 2H_2O$$

From the first test which was terminated prematurely, the estimated reaction percentage was determined to be about 90-95% for carbon monoxide, see Figure 3. The method of calculation of the value was

$$\% = [C_{CD}/(C_{CD} + C_{CM})] * 100\%$$

where C_{CD} is the concentration of carbon dioxide, and
C_{CM} is the concentration of carbon monoxide.

Data for hydrogen was not given in the data base so hydrogen reaction was assumed at least equal to and possibly better than the carbon monoxide reaction percentage. For the calculation the reaction percentages were assumed 80% for carbon monoxide reaction (even with conservative reaction percent the CO seems to remain well below the 10% LEL for personnel entry into an enclosure) and 90% for hydrogen reaction (assumed equal to previous test CO reaction percentage).

In the calculation performed, the primary assumption were

1. no free O_2 leaves the melt (all oxygen combines with C to form CO),

2. single melt rate of 3.5 inches deep/hour,

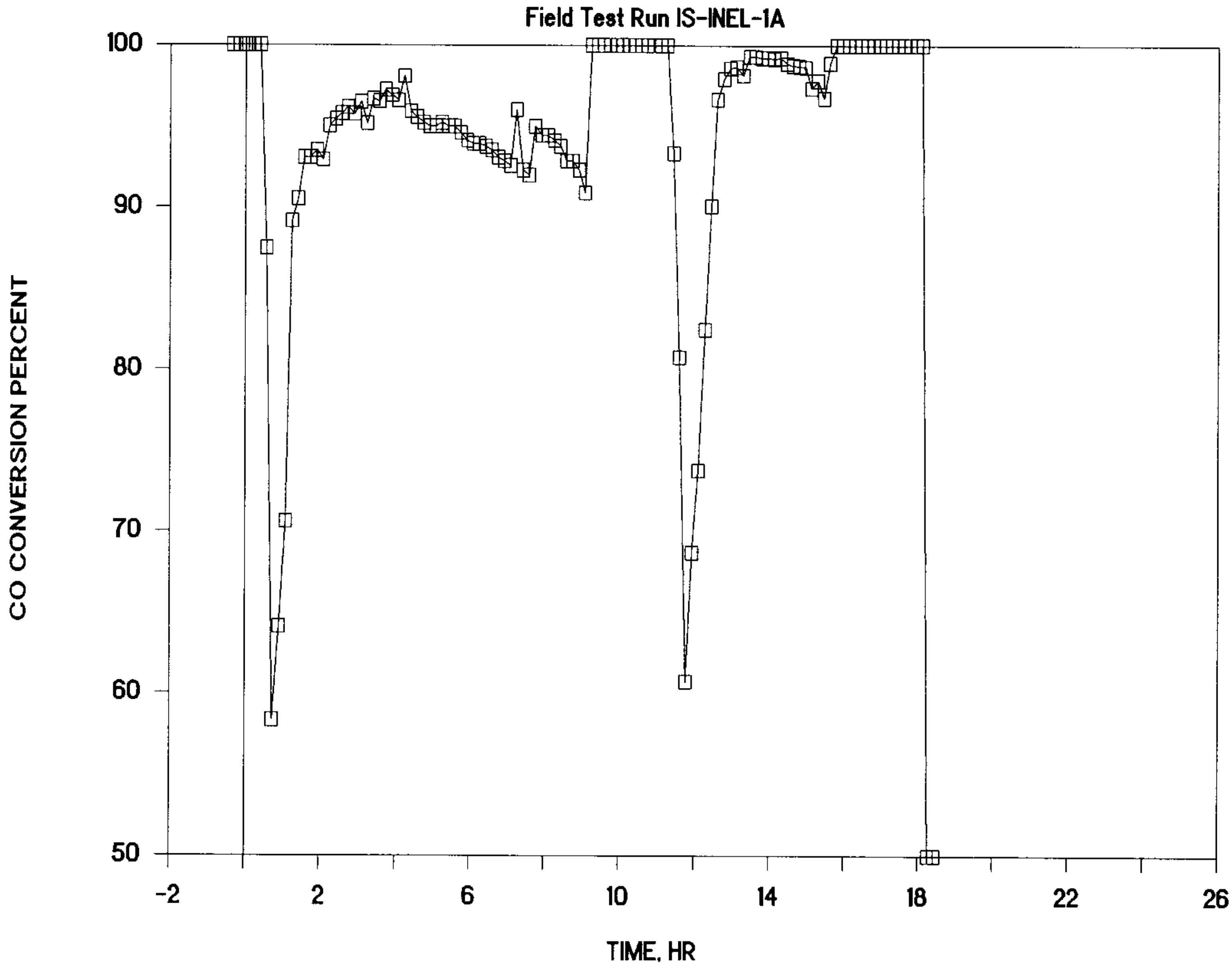
3. melt area is square dimensioning 6 feet to 10 feet (6 feet being the most likely area),

4. and the conversion percentages are 90% for hydrogen to water and 80% for carbon monoxide to carbon dioxide.

5. RESULTS

The set of graphs in Appendix 1 shows the concentration of the off gas just before the gases break the surface of the melt for both pits. Just the gases involved in the combustion are shown. The graphs indicates the concentration of the gases in the melt if complete pyrolysis of combustible material was assumed. These gases will then break the surface

FIGURE 3. CO CONVERSION PERCENT



of the melt and will mix with the hood incoming air. The CO and H_2 gases will combust to carbon dioxide and water, respectively. The various layers in the pits' construction are indicated by the different concentration of the gases; the layers were loaded differently in the amount of combustibles. The maximum amount of hydrogen produced in Pit 2 in the pallet layer and was 25.7% of the off gas volume which is being released from the melt. If this concentration is mixed thoroughly with the incoming air and no combustion occurs, the hydrogen concentration in the hood would be 9.9% which is twice the lower explosive limit as defined by Sax (Sax, N.I. and Lewis, R.J., Dangerous Properties of Industrial Materials, Seventh Edition, Reinhold, New York, 1989). But combustion will occur so it is very unlikely that this concentration will occur during normal operation.

The second set of graphs in Appendix 2 shows the concentration of the off gas just after the air mixes thoroughly with the melt gases and with a combustion conversion of 90% for H_2 and 80% for CO. These are the concentrations which will exit the hood into the off-gas system. The calculation assumes complete mixing and no concentration gradients. Two cases are shown on each graph the upper curve is for 100% of the pit melting and the lower curve is for 36% (6' by 6') of the pit melting. If there was 90% conversion of hydrogen to water and 80% conversion of CO to CO_2, the concentration of hydrogen would be 1.2% or 30% of the LEL for 100% of the pit melting. The lower curve would be the most likely case since the melt occurs mainly between the electrodes and will extend only beyond them just a short distance. With the reduced melt area, the hydrogen concentration in the worst layer (pallet layer in Pit 2) is only 0.43% of the off gas volume. This is the concentration of hydrogen expected from the worst layer during normal operation.

The data considers the variation of the combustible material throughout the vertical depth of the two pits. In pit 1, the pallets left on the boxes were independently considered in a 3.5 inches depth. Each layer was considered uniform for the material placed in the layer. The pallets were again independently considered in pit 2 over a 6 inch depth.

6. DISCUSSION OF RESULTS

The results indicate that the maximum concentration of hydrogen in the off-gas system during operation in either pit is 0.43%, which is slightly above the 10% of LEL for personnel entry into an enclosed area. For pit 1 the values in all cases are below this limit. In actuality the concentration should be lower than this value during normal operations for the test partially conducted in the late summer of 1989 indicated a conversion percentages in the 90% range for carbon monoxide, see Figure 3. Also the melt area is estimated at 6′ by 6′ which may be slightly higher. Also the large amount of steam in the off gas may act as a suppressant to explosion and therefore the LEL will be higher than 4.1% for hydrogen gas in dry air.

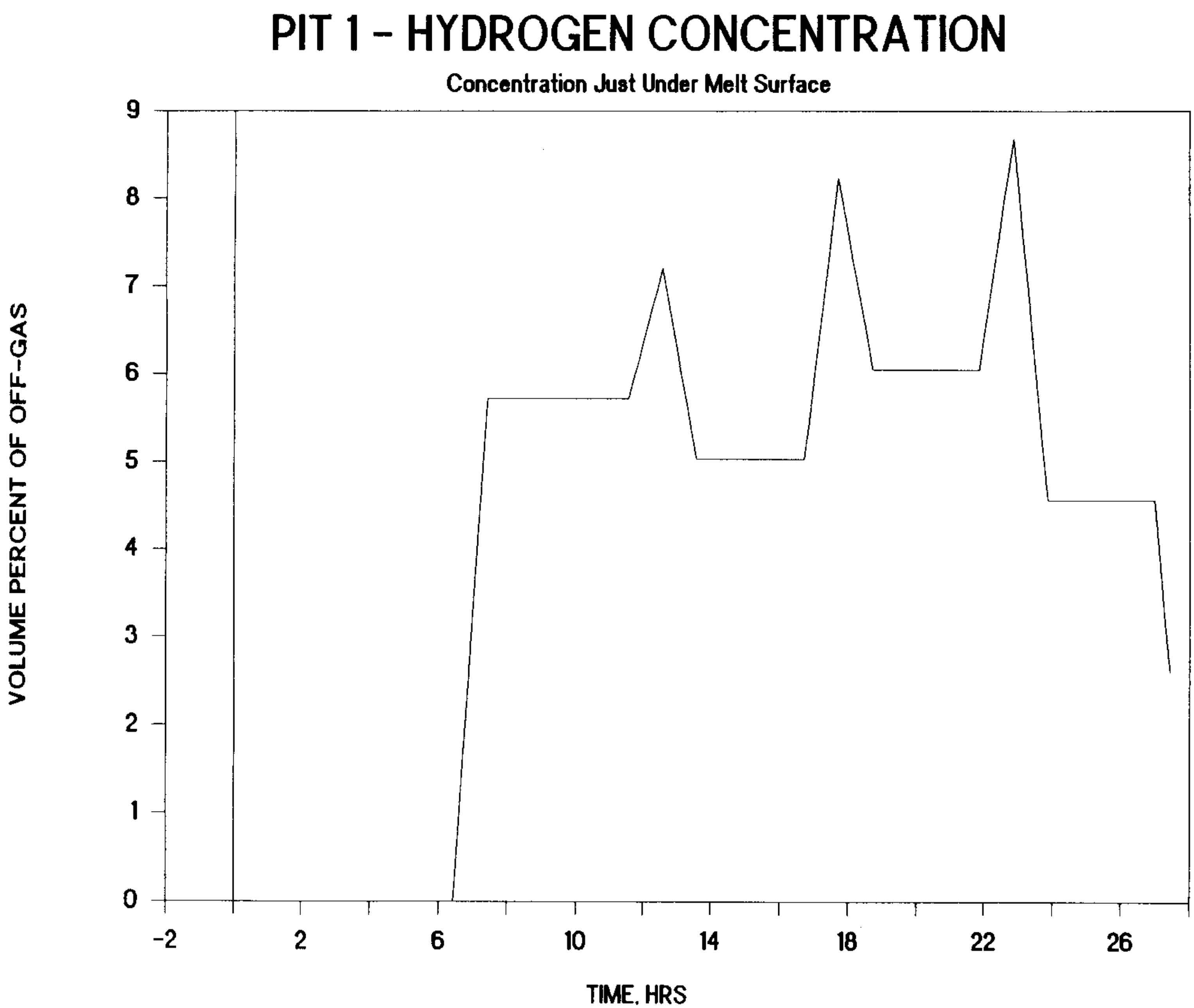
7. SUMMARY WITH RECOMMENDATIONS

This EDF has indicated that during normal operation of the ISV intermediate scale facility, the concentrations of CO and H_2 are expected to be below the LEL for these gases in dry air by a factor of 10. The levels which the facility will operate are levels which are acceptable for entry into an enclosure for explosive gases.

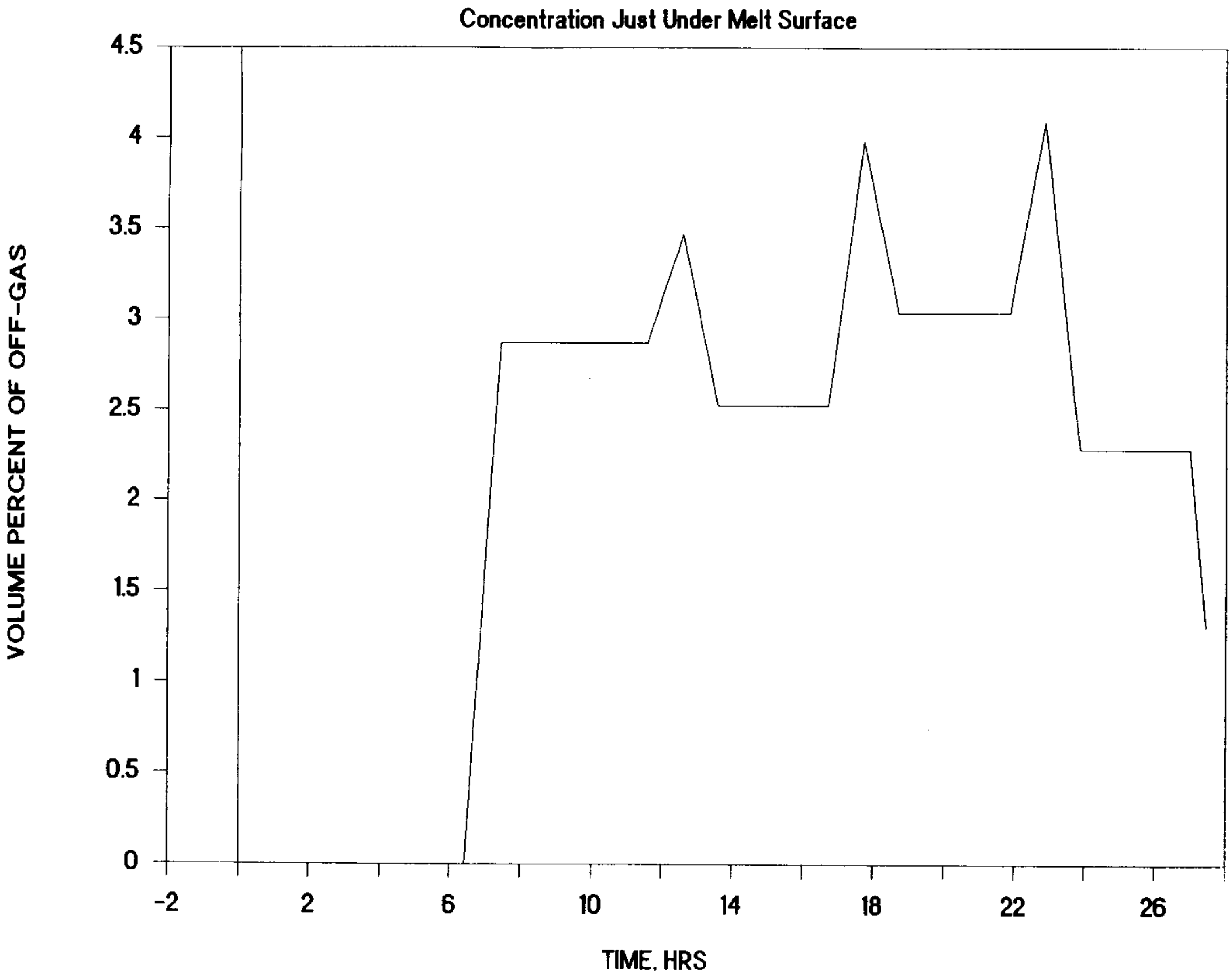
Administrative control for the off-gas system specifies if the stack CO concentration is greater than 0.1%, the CO concentration will be monitored in the operation trailer. Therefore, guaranteeing that the personnel in the trailer are not being exposed to a similar CO concentration. Safe CO concentration level inside the trailer can be interpreted as the stack gases are being adequately dispersed away from the trailer. If the CO concentration in the stack exceeds 2.5%, action will be taken by the operator to lower the emission of CO or shutdown the facility if efforts bring about no lowering of the concentration.

If the blower operation is disrupted, operators should be concerned with the potential of increased concentration of CO and H_2 in the hood because of the lack of reactive air. Since the concentrations of CO and H_2 just below the melt surface are substantially higher than the LEL for their gases, an explosion hazard could ensue. It is recommended that a study be conducted considering this case and determine the time for safe restart (concentration of gases are below their LEL for dry air).

APPENDIX 1

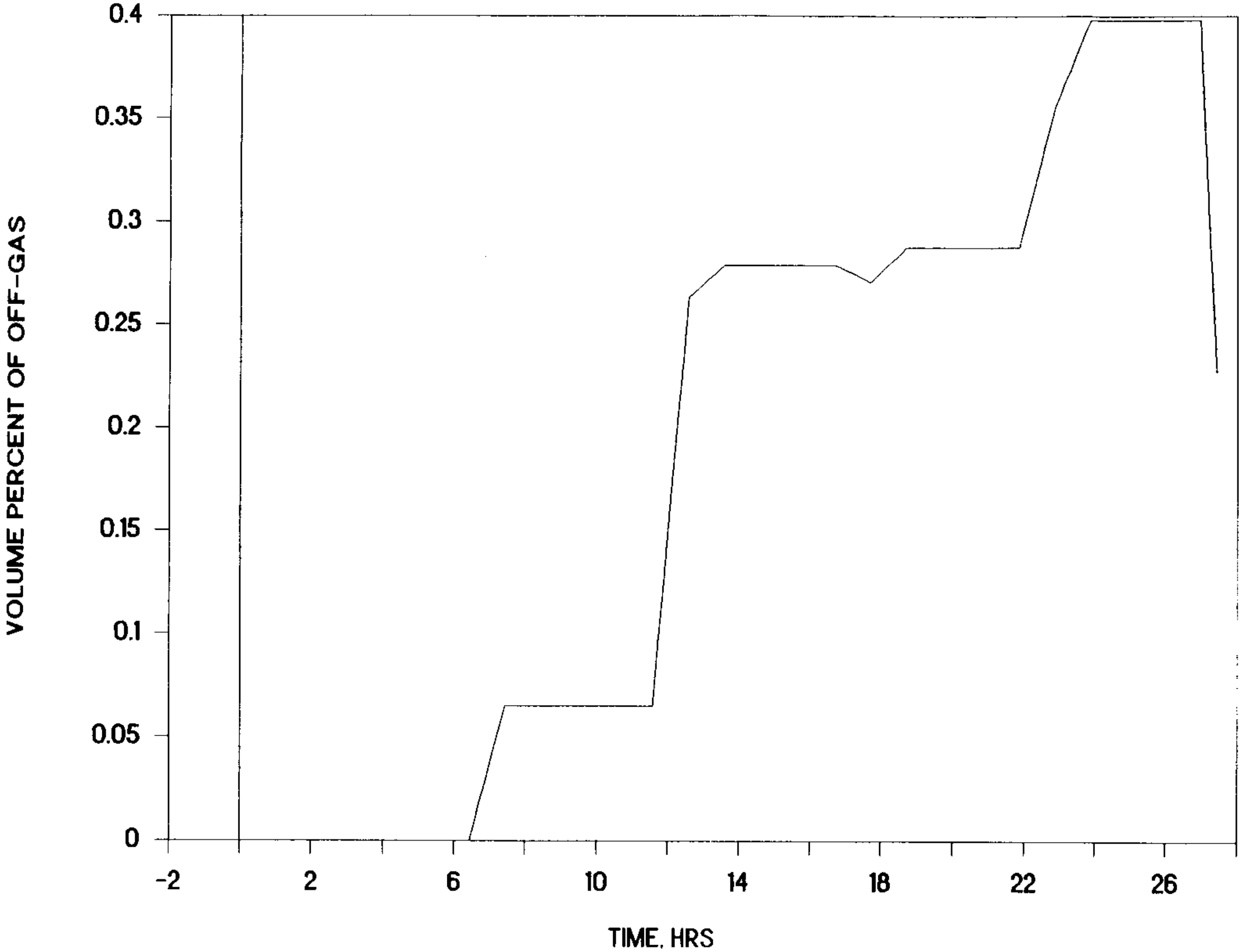

PIT 1 - HYDROGEN CONCENTRATION
Concentration Just Under Melt Surface
VOLUME PERCENT OF OFF-GAS
0
1
2
3
4
5
6
7
8
9
-2
2
6
10
14
18
22
26
TIME, HRS

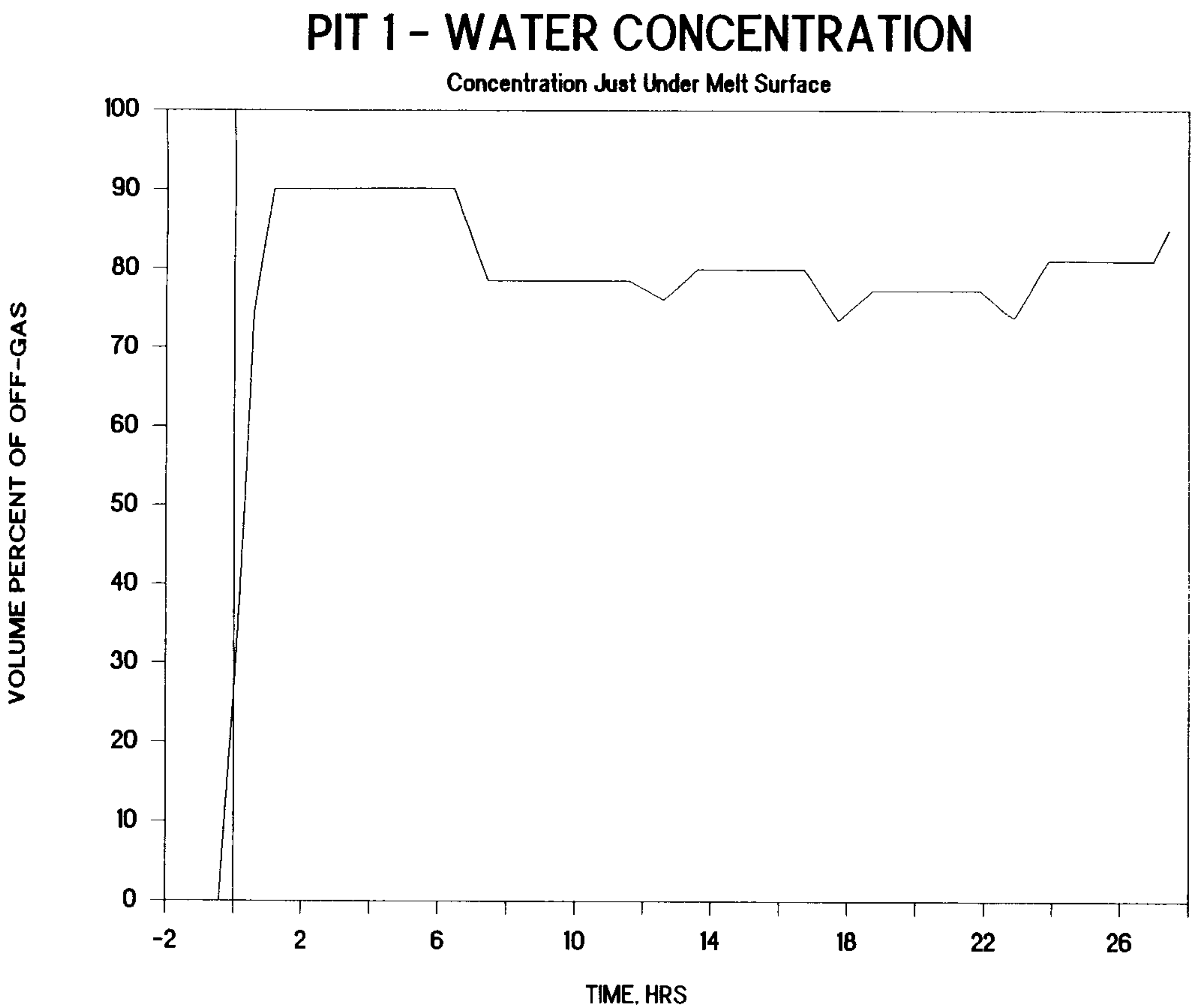
PIT 1 - CARBON MONOXIDE CONCENTRATION

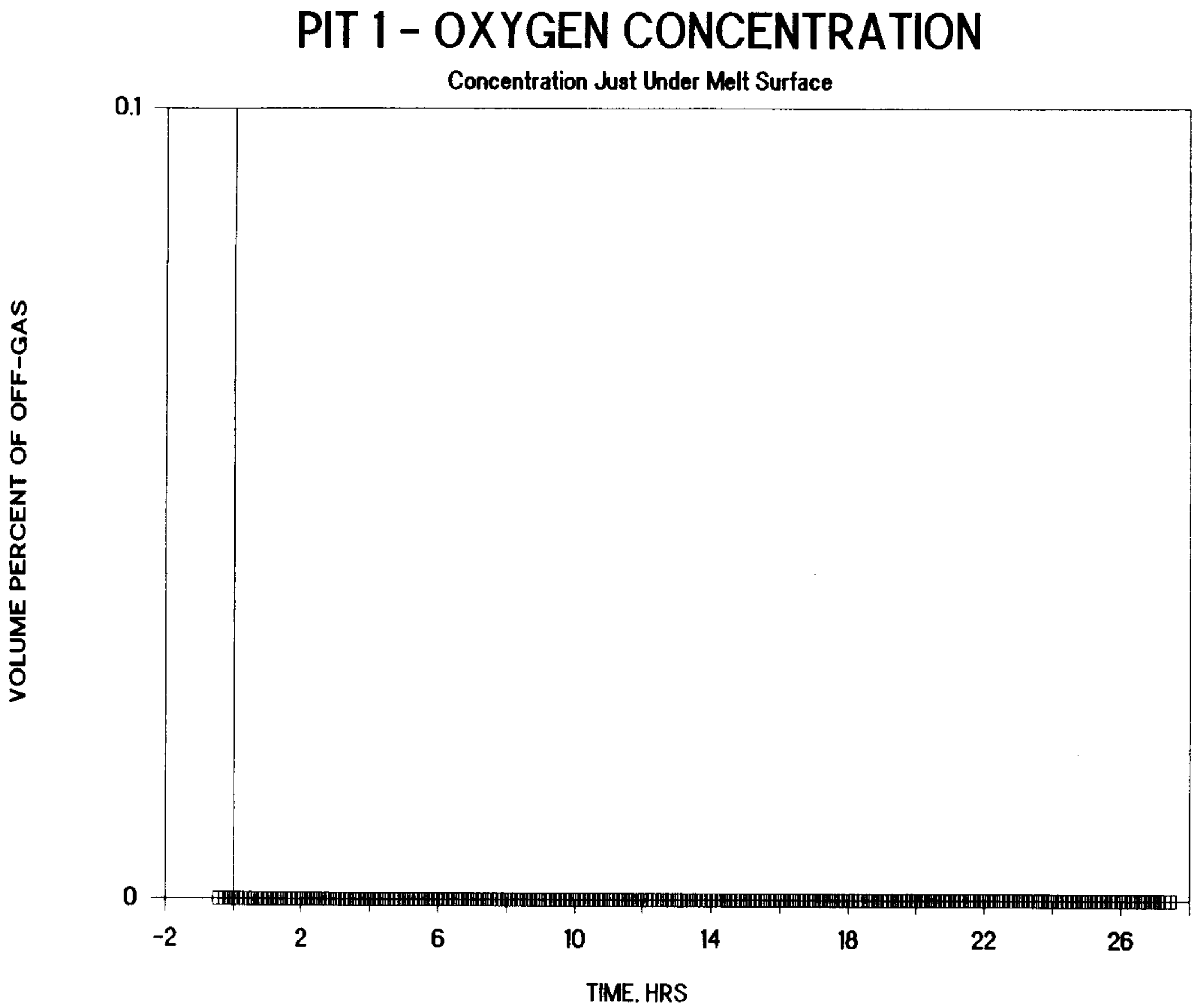


PIT 1 - CARBON DIOXIDE CONCENTRATION

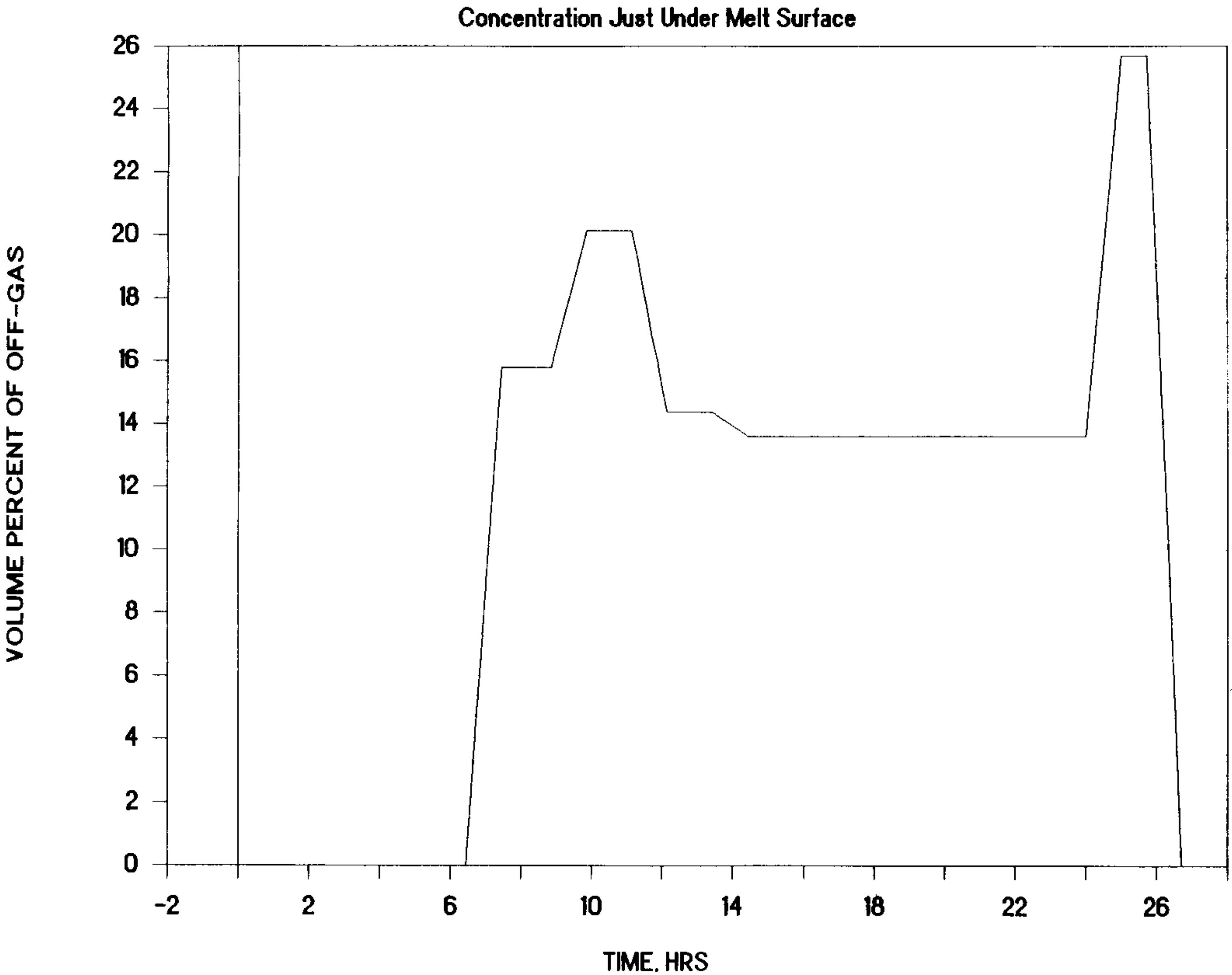
Concentration Just Under Melt Surface

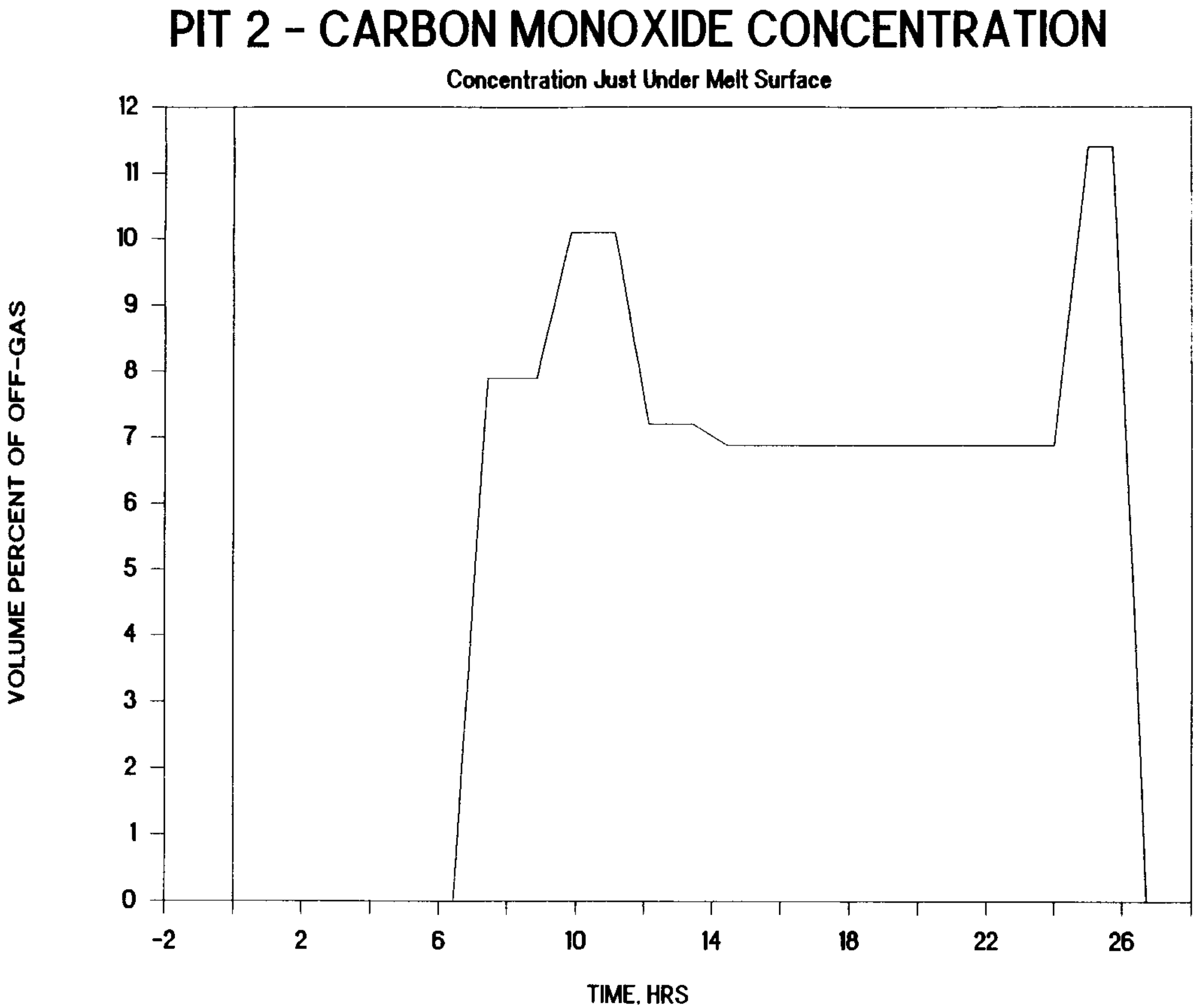



PIT 1 - WATER CONCENTRATION
Concentration Just Under Melt Surface
VOLUME PERCENT OF OFF-GAS
100
90
80
70
60
50
40
30
20
10
0
-2
2
6
10
14
18
22
26
TIME, HRS

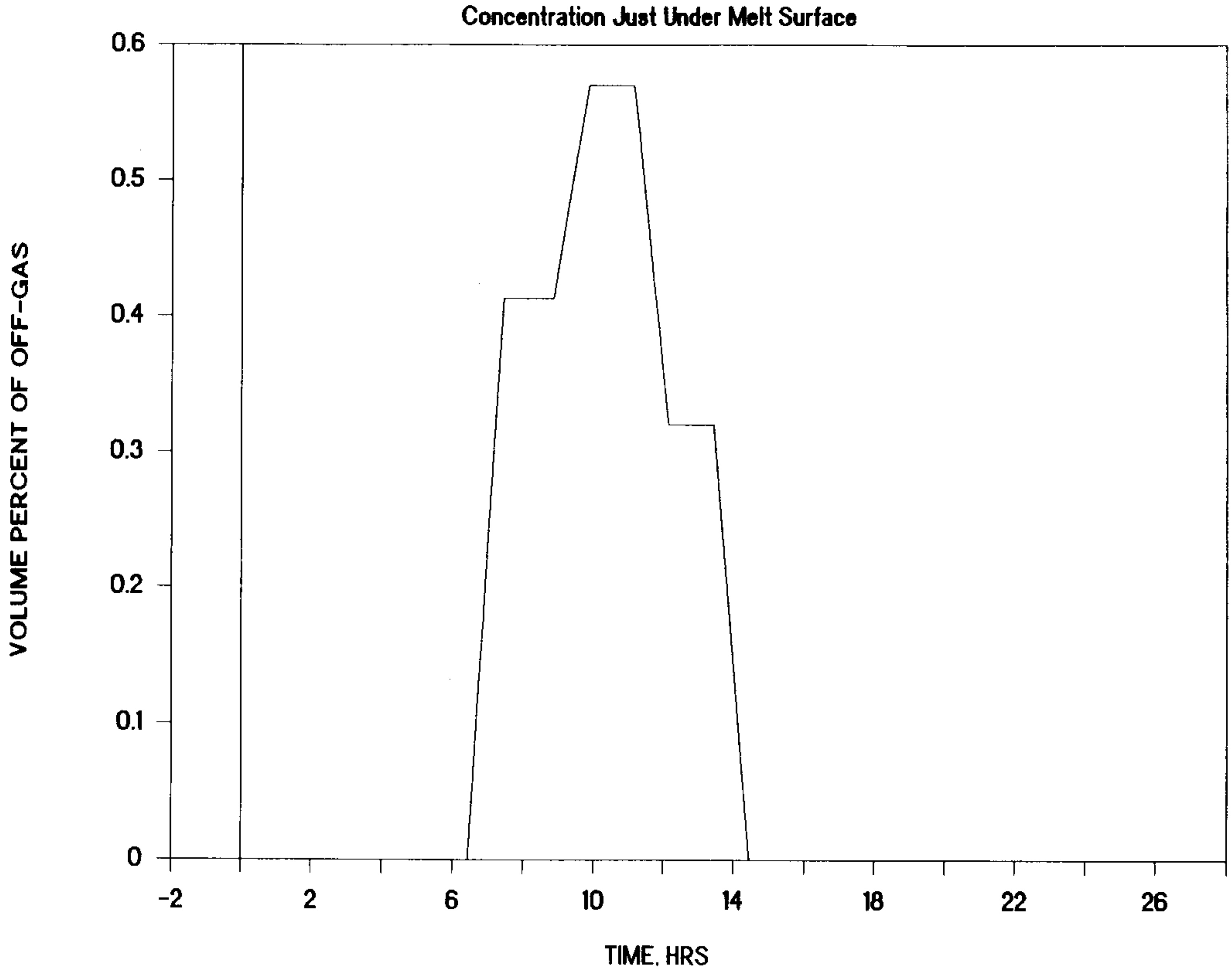

PIT 1 - OXYGEN CONCENTRATION
Concentration Just Under Melt Surface
VOLUME PERCENT OF OFF-GAS
0.1
0
-2
2
6
10
14
18
22
26
TIME, HRS

PIT 2 - HYDROGEN CONCENTRATION

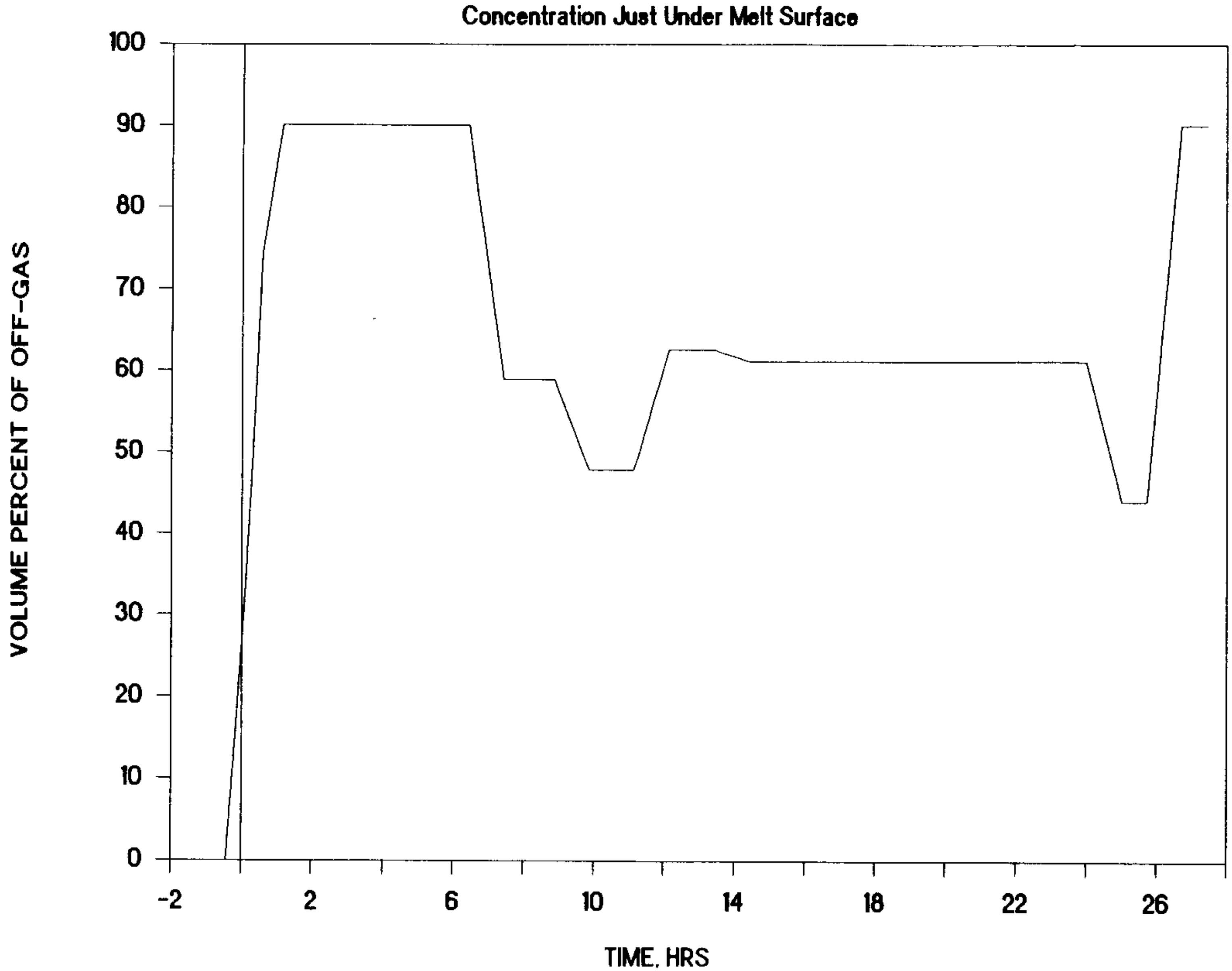


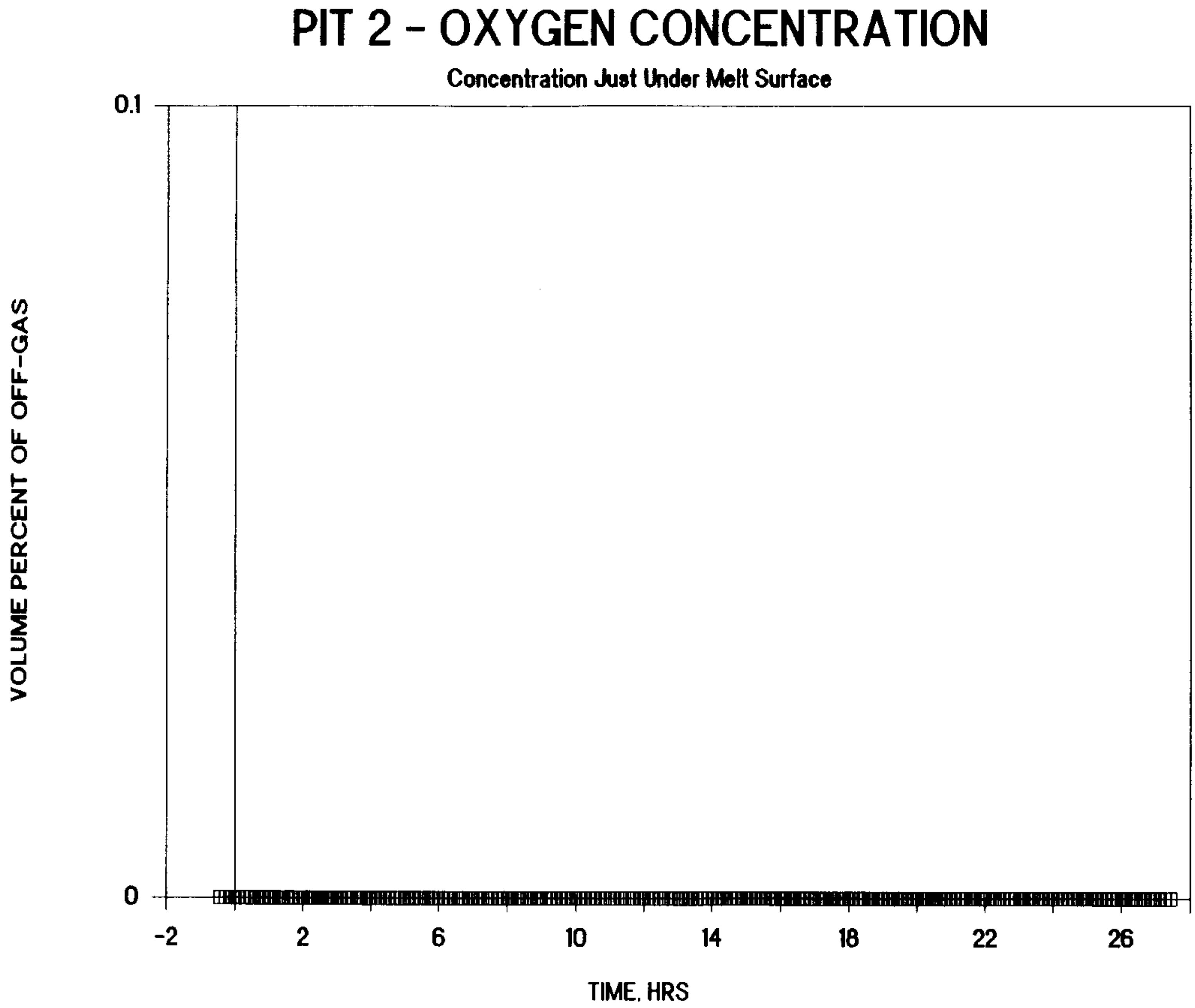

PIT 2 - CARBON MONOXIDE CONCENTRATION
Concentration Just Under Melt Surface
VOLUME PERCENT OF OFF-GAS
12
11
10
9
8
7
6
5
4
3
2
1
0
-2
2
6
10
14
18
22
26
TIME, HRS

PIT 2 - CARBON DIOXIDE CONCENTRATION

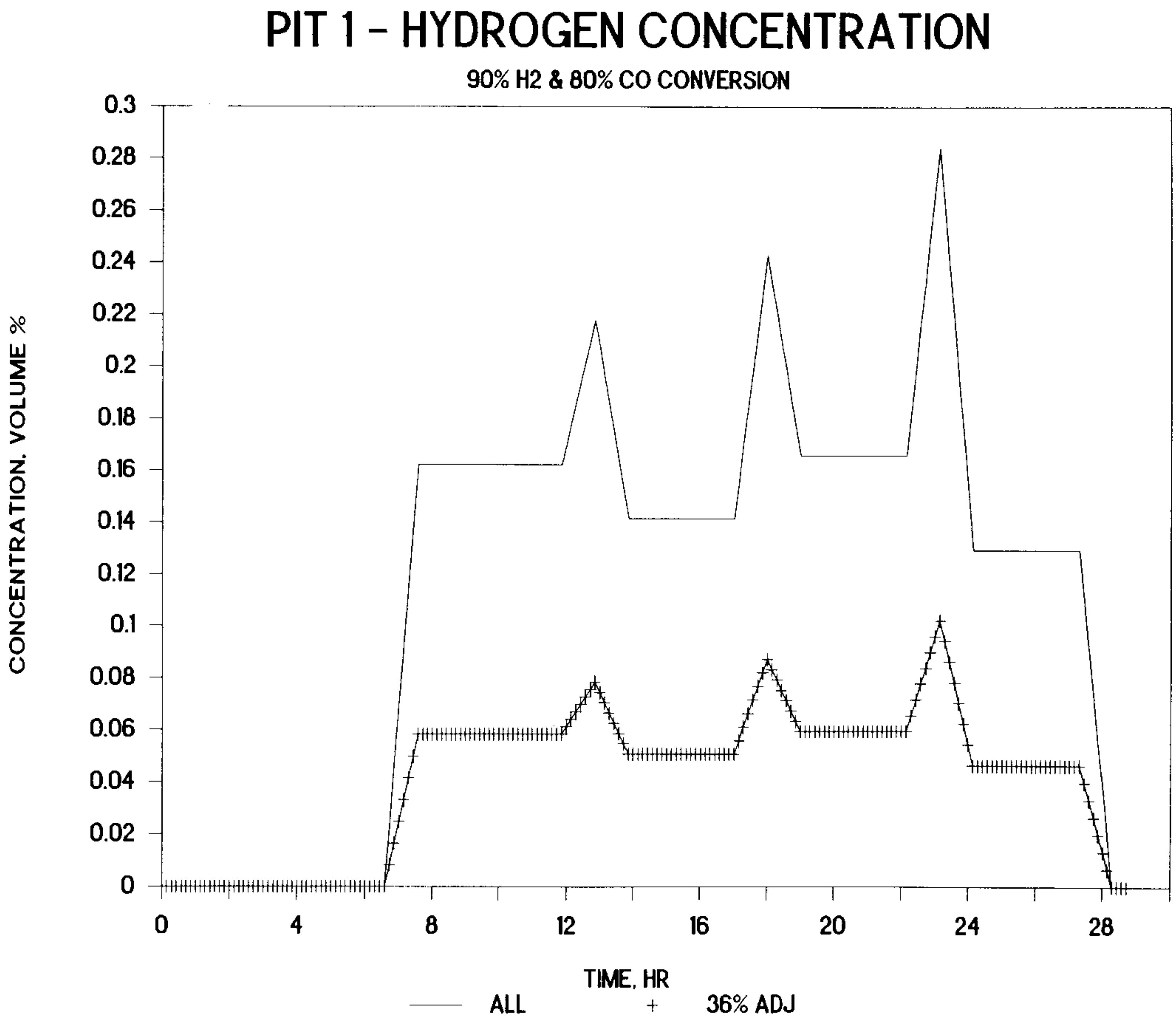


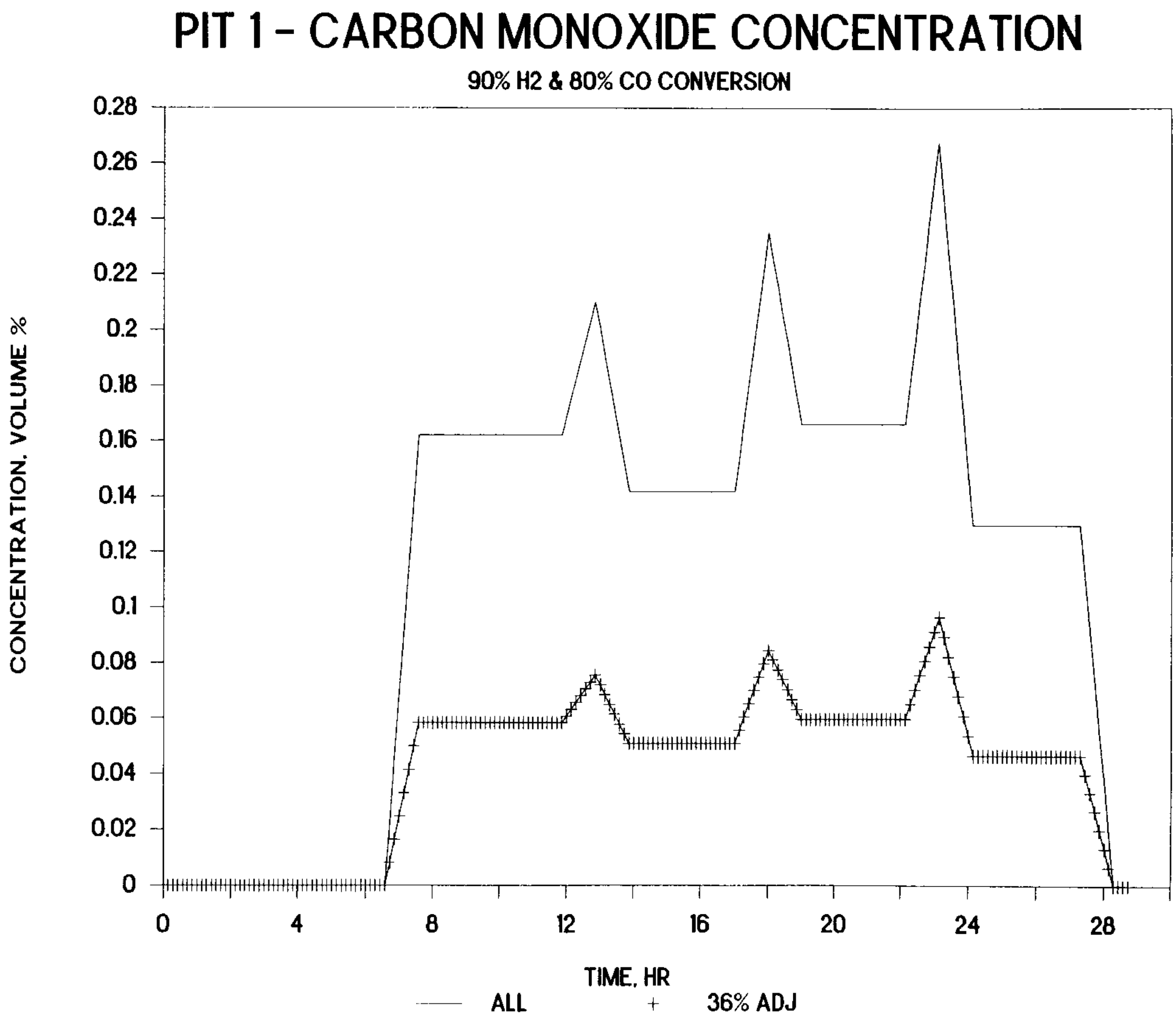
PIT 2 - WATER CONCENTRATION

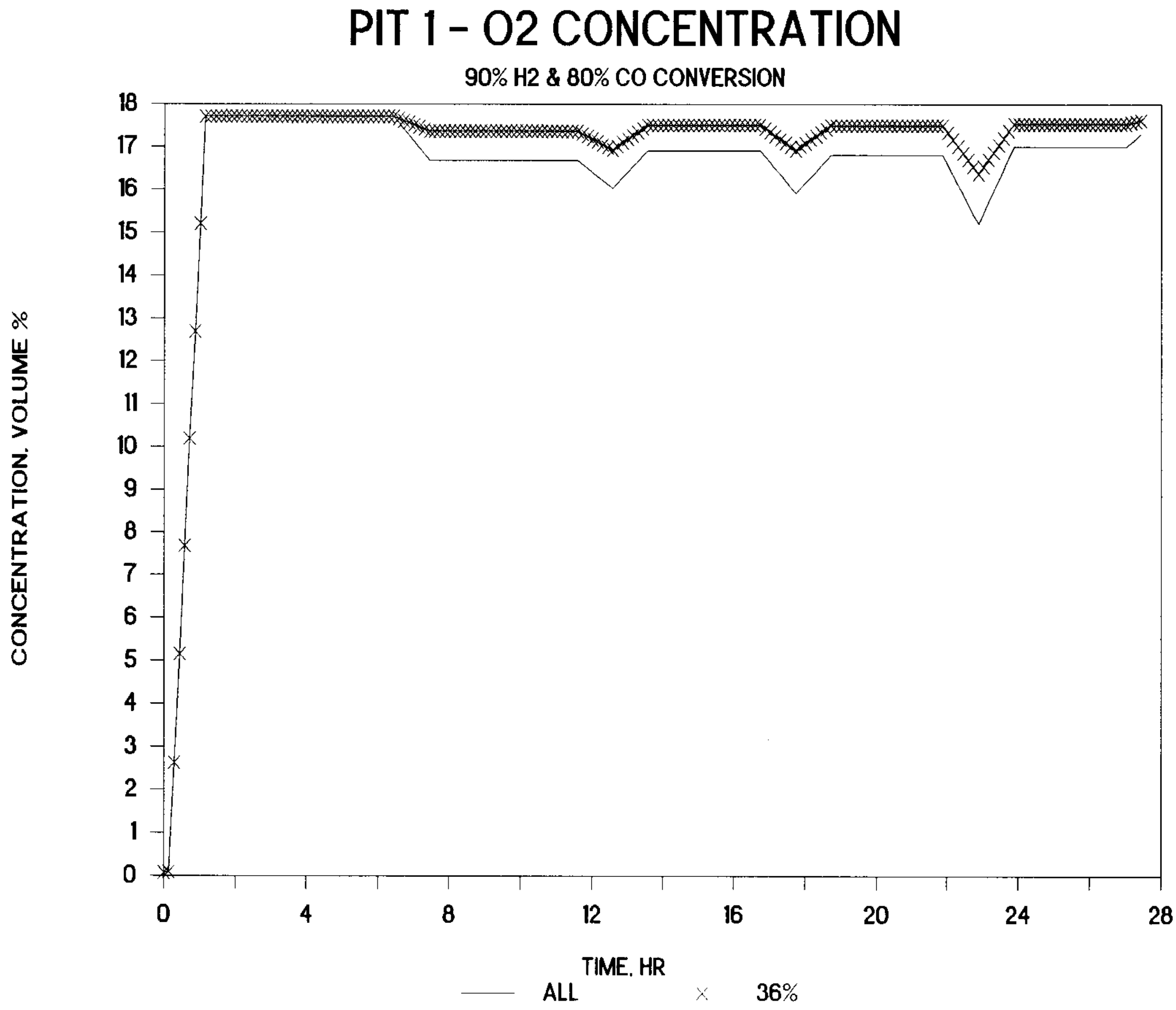



PIT 2 - OXYGEN CONCENTRATION
Concentration Just Under Melt Surface
VOLUME PERCENT OF OFF-GAS
0.1
0
-2
2
6
10
14
18
22
26
TIME, HRS

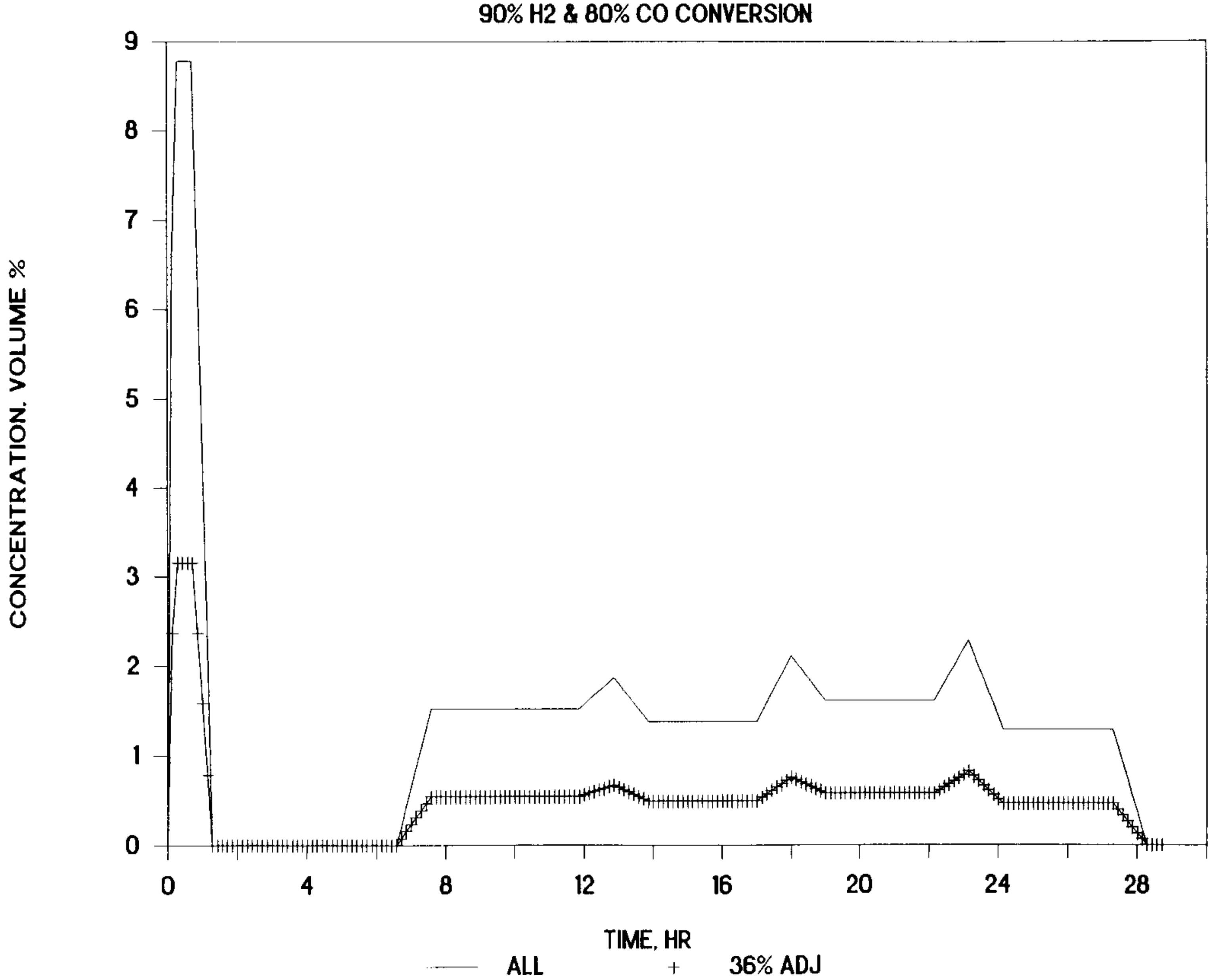
APPENDIX 2


PIT 1 - HYDROGEN CONCENTRATION
90% H2 & 80% CO CONVERSION
CONCENTRATION, VOLUME %
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0.28
0.3
0
4
8
12
16
20
24
28
TIME, HR
ALL
+ 36% ADJ


PIT 1 - CARBON MONOXIDE CONCENTRATION
90% H2 & 80% CO CONVERSION
CONCENTRATION, VOLUME %
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
4
8
12
16
20
24
28
TIME, HR
ALL
36% ADJ

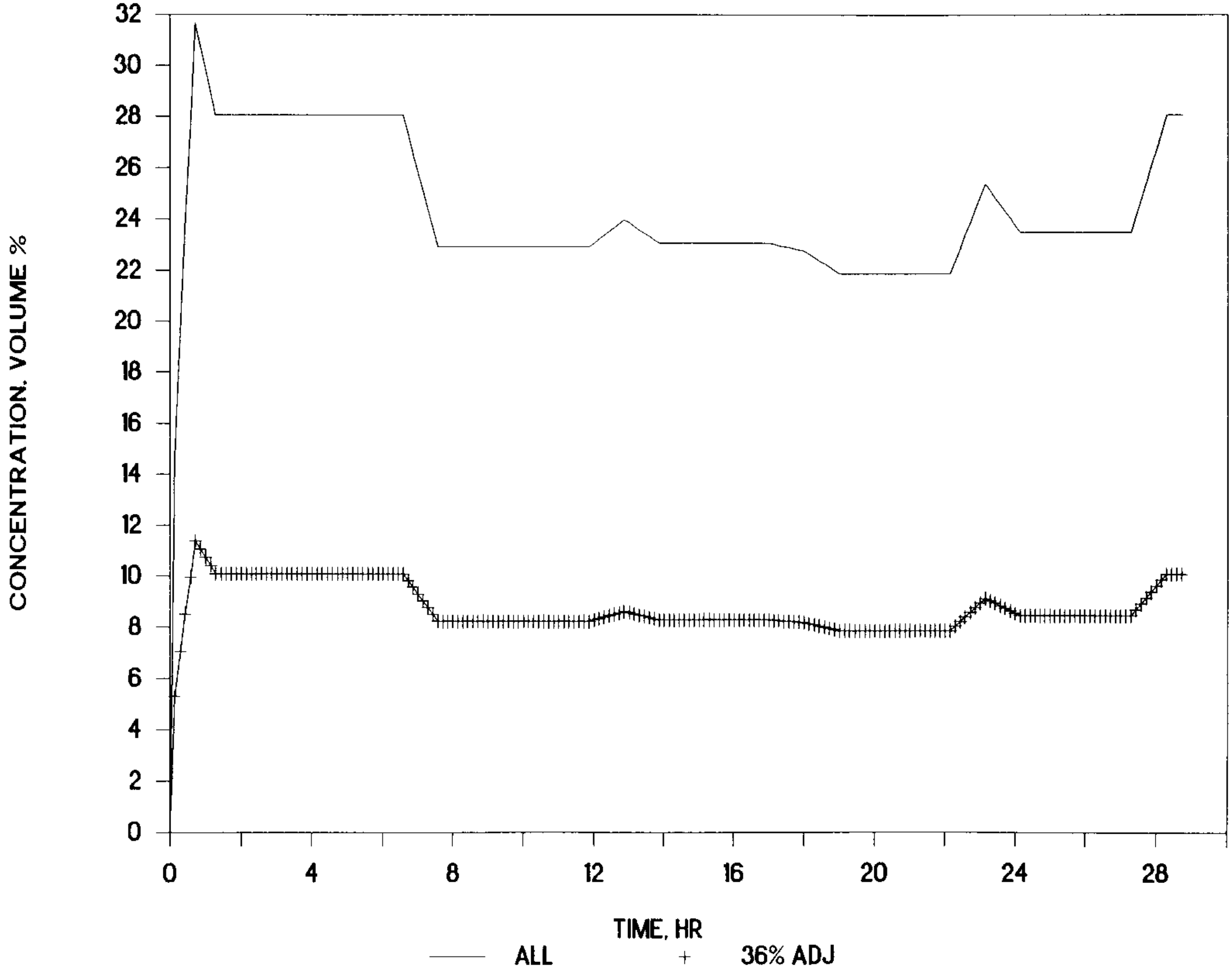

PIT 1 - O2 CONCENTRATION
90% H2 & 80% CO CONVERSION
CONCENTRATION, VOLUME %
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
4
8
12
16
20
24
28
TIME, HR
ALL
36%

PIT 1 - CO2 CONCENTRATION

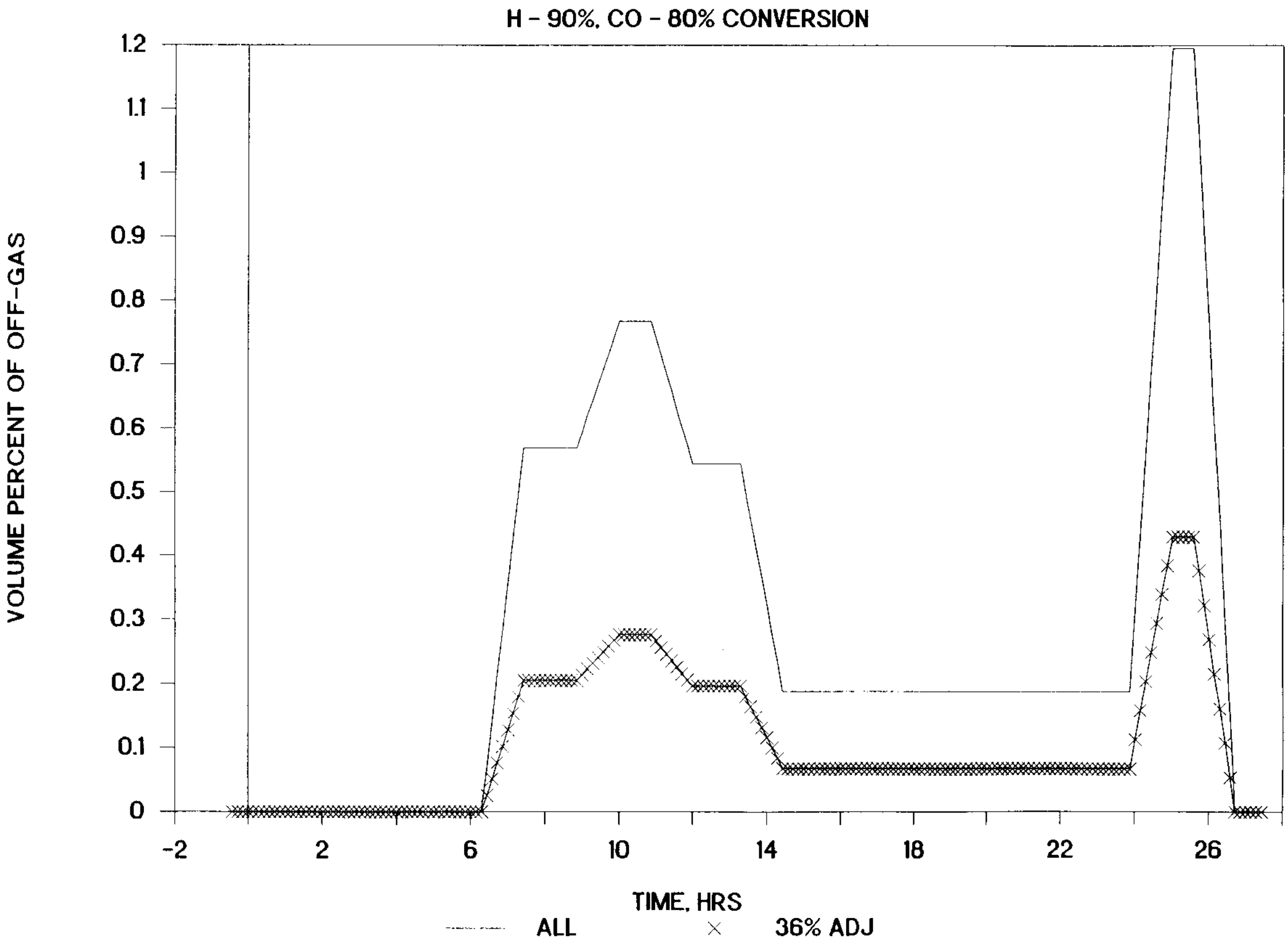


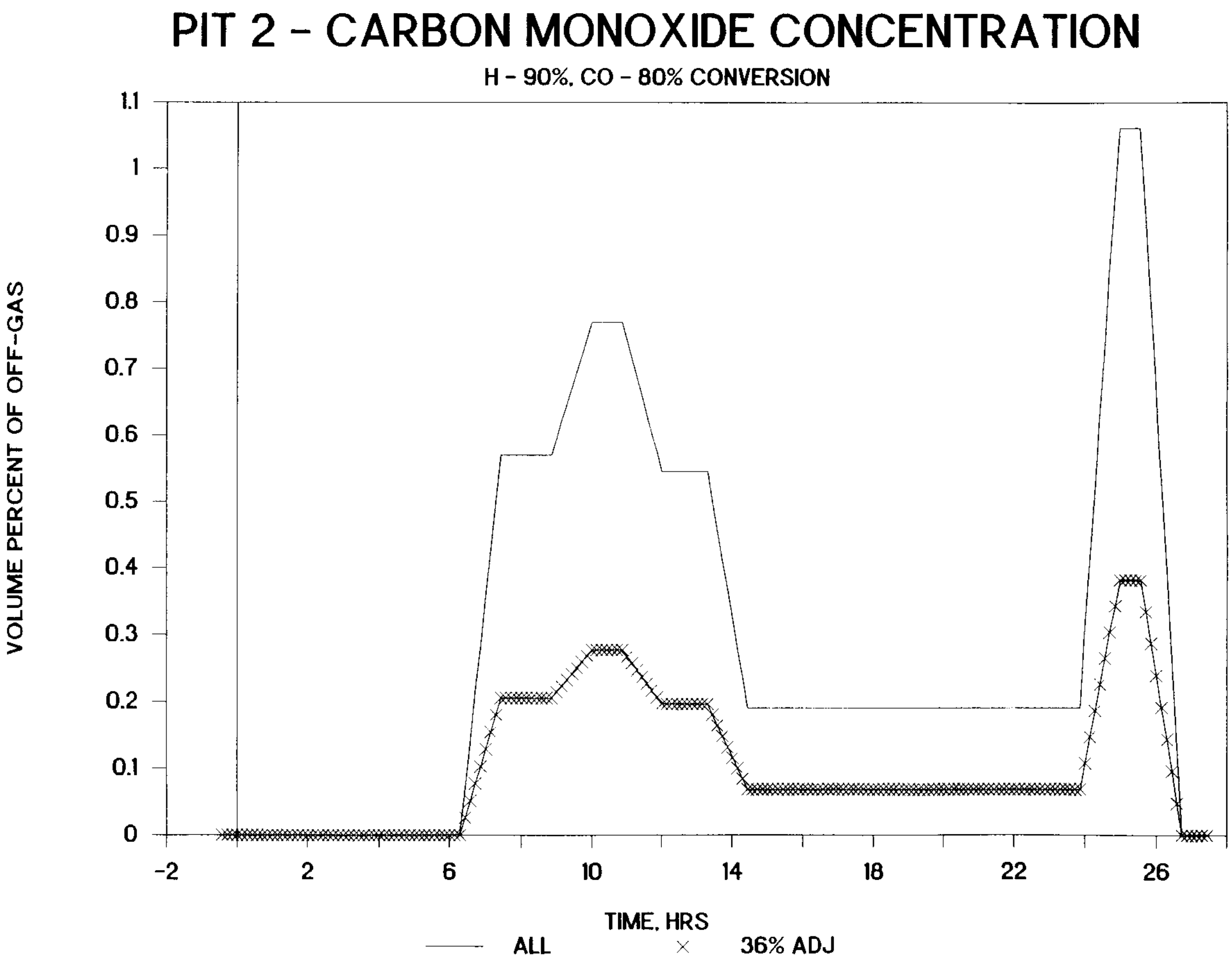
PIT 1 - H2O CONCENTRATION

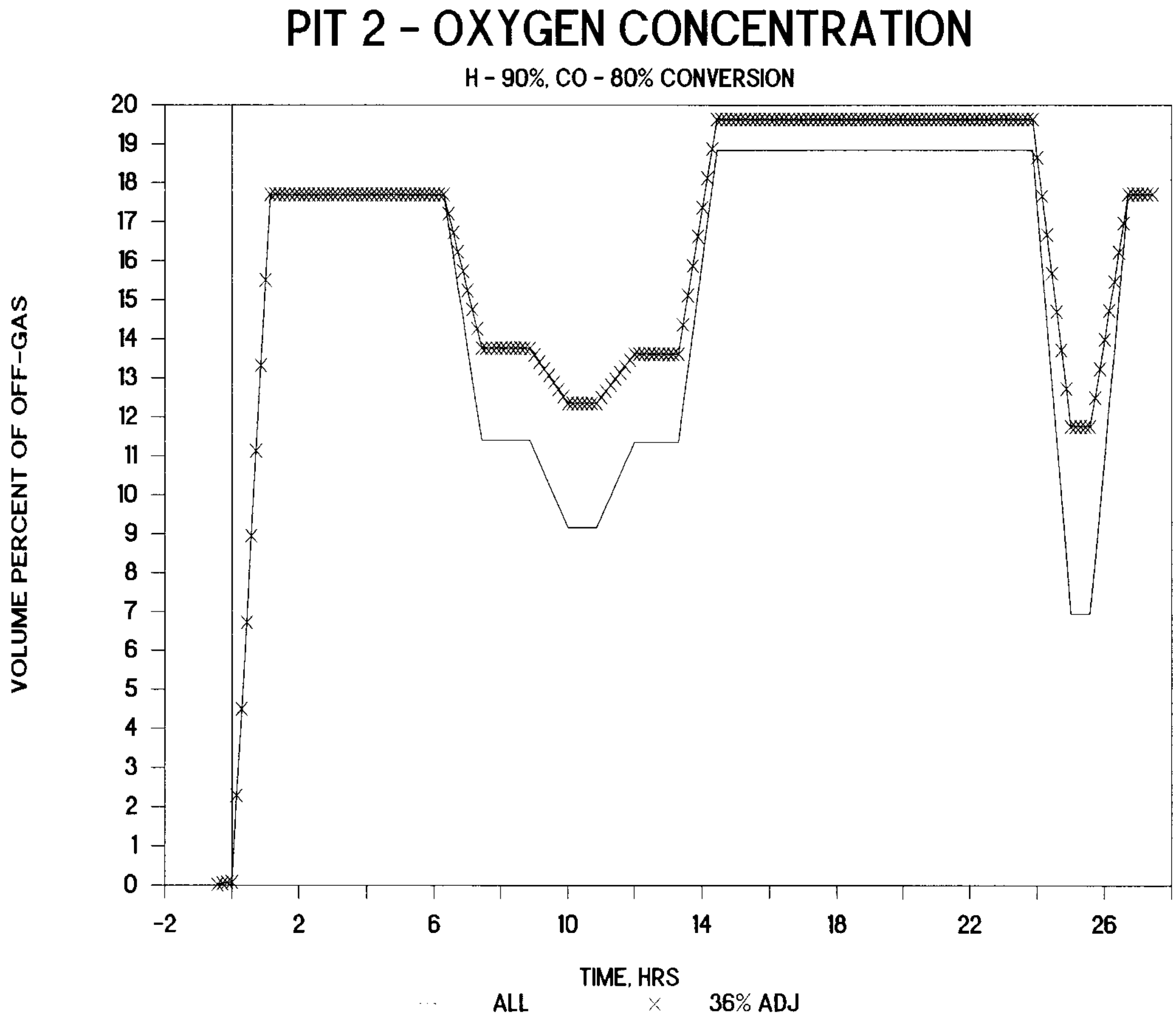
90% H2 & 80% CO CONVERSION



PIT 2 - HYDROGEN CONCENTRATION




PIT 2 - CARBON MONOXIDE CONCENTRATION
H - 90%, CO - 80% CONVERSION
VOLUME PERCENT OF OFF-GAS
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-2
2
6
10
14
18
22
26
TIME, HRS
ALL
36% ADJ


PIT 2 - OXYGEN CONCENTRATION
H - 90%, CO - 80% CONVERSION
VOLUME PERCENT OF OFF-GAS
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-2
2
6
10
14
18
22
26
TIME, HRS
ALL
36% ADJ

PIT 2 - CARBON DIOXIDE CONCENTRATION

H - 90%, CO - 80% CONVERSION